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Status of the adoption of social media in the scientific research community

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Abstract. This paper takes a broad view of the current status of the use and role of Social Networking by scientists and researchers. Facets of the study include the styles of scientific collaboration and how they differ from current social media capabilities, a look at the present scientific collaboration sites, what the trends are in the marketplace, and how this paradigm has the potential to change the landscape of the traditional refereed journals. These studies are based on a combination of research, technology reviews and statistical analysis of research collaboration using the U.S. Department of Energy-funded published research results.

Keywords: Social media, scientific collaboration, research, trends

1. Background

Information International Associates, Inc. (IIa) was awarded a Department of Energy (DOE) Small Business Innovative Research (SBIR) grant to study Interactive Peer-to-Peer Scientific (P2P) Communication in the Digital Library Environment. IIa was also awarded a DOE Experimental Program to Stimulate Competitive Research (EPSCoR) grant to explore "Exploiting the Use of Social Networking to Facilitate Collaboration in the Scientific Community". The authors served as the Principal Investigator (PI) and Contracting Officer's Technical Representative (COTR), respectively, on both grants. Although the grants were focused in two entirely different perspectives of scientific collaboration, a synergy was identified in the research that provided significant insight into the overarching concept of the role of social media in scientific collaboration. This paper refers to the combined research as "the project" so that the reader does not need to be concerned with the details of which grant yielded the observations described herein. Initially, the project included activities in three main areas:

1. Review of Web 2.0 technologies that could be applied to P2P scientific communication;
2. Analysis, prioritization, and development of concepts and applications to provide the starting point and foundation for a community of experts and their online interaction;
3. Research of barriers to the adoption of social networking concepts for scientific collaboration.

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2. Review of Web 2.0 technologies

To evaluate the current state of technology in collaboration tools while keeping an eye toward understanding their value in building profiles for science-based professionals, the project team performed an in-depth review of two social networking websites: the social networking framework, Socialtext [5] and the Department of Defense's (DoD's) Aristotle.

Regarding Socialtext, the team evaluated collaboration features and tools in a test-trial implementation. The team characterized Socialtext as a software application that combines Facebook, Wiki, Twitter and blogging features smashed together in an iGoogle dashboard view for the enterprise. Due to its complexity, Socialtext is somewhat overwhelming initially. However, since it is very sophisticated, it can accomplish many project tasks. In general, to gain acceptance by a broad range of non-technical users, it is necessary to organize and adjust features in certain ways.

With Aristotle, "a Web-based professional networking tool designed for federal government and DoD employees and contractors in the science and technology (S&T) community" [4], the project team performed a site review and identified strengths and weaknesses of the platform, the user interface and performance.

The team also performed a broad, high-level review of widely adopted, science-based social networking websites. Below is a high-level summary review of the other science-based social networking applications identified.

- Academia.edu: targets academics and researchers from all disciplines, and assists users in following current research in their fields; launched in 2008 and has approximately 275,000 users. Allows users to find colleagues, review/follow work and upload and share papers.
- biomedexperts.com: literature-based scientific, worldwide social network provided at no charge by Elsevier, Inc., allowing researchers with similar interests in biomedical research to collaborate online, with over 24 million co-author connections between 1.8 million researchers and collaborators from over 3,500 institutions in 190 countries. Networks were automatically generated from co-author information from millions of publications published in over 20,000 journals.
- www.epernicus.com: allows for creation of a scientific profile, connection with current and former colleagues, and location of people and expertise within a scientific network.
- labroots.com: enables scientists, engineers and other technical professionals to connect, collaborate with, and learn from each other at no charge. Includes profiles, an event calendar, private messaging, groups, publications, a question and answer forum, blogs, reviews and jobs.
- mendeley.com: allows researchers to organize their own research library, share with other researchers and discover new research and trends. The researcher can share documents, collaborate and build their personal research network. At the time the site was last visited, there were 7,982 research institutions using Mendeley, 22,694 research groups collaborating, 18,947,397 documents in people's libraries.
- Nature Network (network.nature.com) a free social networking website for scientists provided by Nature Publishing Group (NPG), publisher of the journal *Nature*. Provides profiles, blogs, groups, forums, question and answer and workbench. (Connotea, a reference management tool, is also a service of NPG.)
- ResearchGate (www.researchgate.net): a free social networking website touted as a "Facebook for scientists"; includes semantic searching of abstracts and external research databases, and can use an entire abstract for search terms. Allows blogs and provides automated suggestions for groups, other members, and literature based on research interests. Includes 1,100 groups and file sharing tools.

- scienceonline2011.com: the fifth annual international meeting of Science and the Web, which was "held in an 'unconference' style". Participants on a wiki built the program, with sessions designed for collaborative conversation and discussion instead of traditional lectures.
- ScienceStage.com: science-oriented multimedia platform and network for scientists that can publish video and documents and form groups. Functions as a learning, publishing and presentation tool.
- Scientist Solutions (scientistsolutions.com): began in 2004 to promote worldwide advancement of science and biotechnology. Includes an internet discussion board where scientists exchange ideas and information. Still includes the original core offering of serving as a discussion board for life scientists. Also includes profiles, blogs, protocol finder, event listings and job board.
- ScienXe.org: an independent website creator and international online community for researchers, academics, scientists and students that makes users' web pages more visible in the online scientific community.
- Scispace.net: a service for collaborating researchers that profiles, wikis, blogs, comments, tags and comment walls. Also provides "fine-grained access control".
- http://vivoweb.org/: a scientific network to facilitate discovery of researchers and collaborators across the U.S. Institutions can participate by installing the open source semantic web app or by providing the appropriate data for the network. VIVO was developed at Cornell with a $12.2 million grant from the National Institutes of Health (NIH) to link profiles through publications, grants and data.

The list below provides a high-level summary of social networking applications which were reviewed for their contributions to the concept of *social profiles*.

- LinkedIn (linkedin.com): considered the authoritative profile for professionals, although not used on a daily basis by most users. Combines work experience, education, relationships, recommendations, etc., in a single place. Users can explicitly list skills and search terms to locate professionals in their areas of interest.
- Facebook (www.facebook.com): considered the top profile application for non-professional use; users make frequent/daily updates to their profiles. Public and private organizations have Facebook pages or accounts, but this service is used as a more personal networking site by a large majority of users. Profiles can include work and education information, as well as personal interests and hobbies.
- Google Profiles (www.google.com/+): includes simple profile information without social networking features. Allows for linking various social networking accounts into a single location. Of the several sites that enable this, Google Profiles is the most ubiquitous, allowing for automatic association of many accounts. A recent design update has a layout similar to Facebook's highly relevant search capabilities. Auto-suggestion of Google Profile pages when searching for names has been included in the past. Because Google is pervasive in including large amounts of data about people, this profile offering is significant.
- About.me.com: is a new class of profile page that has recently gained popularity. Includes a single page with a picture, short bio and links to other social networking sites. Similar sites do not seem to be as visible as About.me. Users are encouraged to include a picture that captures the essence of their personality.
- Gravatar (en.gravatar.com): similar to Google Profiles, this site began as a way to sync one's photo across social networks and other websites. However, verified links to other social applications have

been added. While Google Profiles allows the user to list any links, Gravatar has the additional benefit of requiring log in to verify that the user actually owns each account.

The team defined a good social profile application as one that gives a good snapshot view of a person's interests and experience. It should also serve as a centralized identity, linking other more specialized niche networks.

3. Analysis, prioritization and development of concepts and applications to provide the starting point and foundation for a community of experts and online interaction

To address this technical objective, the team first focused on developing a clear understanding of the types of collaborations [2] conducted by scientific researchers. Following is a list identifying categories of basic scientific communication activities that support collaboration.

(1) *Collaborate*: Participate in communities of interest, working/project groups, forums for discussions and file sharing.
(2) *Search*: Monitor/review literature/news/events/people to keep current, to find funding sources, to identify expertise and to mine data for experts or research.
(3) *Document original content*: Contribute original ideas and discoveries to the evolving structure of knowledge in a particular field. Also create, annotate, review, reuse and represent information in new ways, including writing and publishing articles, essays, books, etc.
(4) *Promote one's work*: Publish articles, push information to colleagues, announce funding opportunities and disseminate ideas.
(5) *Build peer networks*: Connect personally and topically and learn about research communities beyond one's personal networks.
(6) *Extract/organize information*: Manually and automatically organize and extract information for context, meaning and future retrieval.
(7) *Conduct peer reviews*: Review pre-published scientific articles by other professionals in the same field. (Other peer activities such as peer influence are addressed by activities above, such as building peer networks and raising one's profile through promoting one's work.)

The basic activities shown above, gathered and synthesized from DOE Scientific Advisors and Stanford University Libraries [6] and Research Information Network (London) [8], represent a broad spectrum of communication and interaction that scientists perform during the research process.

With this set of activities, social networking applications and features could be evaluated for their value in supporting research collaboration. The project team concluded that it would be most effective to focus on facilitating the following collaboration and profile building activities identified above:

(1) Collaborate;
(4) Promote one's work;
(5) Build peer networks;
(6) Extract/organize information.

The activities listed above are not effectively accomplished by current online social networking applications; they represent potential areas for improvement. Through analysis, the team determined that extracting and organizing information is critical for making sense of huge amounts of data. Because existing tools can add to the problem of information overload, a concern expressed by scientists, the

team determined that solving this problem is of particular importance for the scientific community. The following activities were viewed as already being addressed by existing platforms, such as scholarly publications and search tools:

(2) Search;
(3) Document original content;
(7) Conduct peer review.

Pursuant to the discussion above, the team decided that the area of research most likely to yield useful results was in the definition and character of the user profiles [1] from a social media type of research collaboration tool. That is, the purpose of profiles is determined to effectively encourage and support interaction among collaborators. To that end, the following are essential profile functions:

- Verify the identity of other users. This is especially valuable for users with similar last names. For example, a user's *affiliation* provided in a profile is used in networking sites to help end-users determine which "Smith" is the author of a particular document.
- Specify different names under which a particular author has published. Because an author may have published under multiple names, being able to make these other names known can help users to identify other works by the same author.
- Provide detailed background information, such as education or work history, to let other users know more about a particular user's credentials or experience with a subject. This additional background may be of interest to researchers when performing topic or author searches, viewing the answers to questions, or understanding the context of online discussions.
- Include research areas and fields of interest to facilitate connections and dialog on topics of mutual interest.
- Broadcast that a user is seeking or offering collaborative opportunities, such as the seeking of industrial partners for a proposal.

Over time, users may increasingly employ profiles as a way that allows them to meet other researchers with similar interests, just as other social networking sites are used today. In the near term, the most predominant use of profiles is expected to be in its supporting role to other applications, such as verifying authors during the search process, or providing more detail about authors.

One critical element to online interaction is trust. Without trusted communication, collaboration cannot take place. In order to achieve the project vision of researchers meeting, talking and collaborating online, it will be essential to provide a level of trust for those interactions. Fortunately, an adequate level of trust can be provided online through identification and verification of participants. The use of profiles is one of the most widely applied, scalable approaches employed by networked systems to identify users. The list of desirable profile fields provided indicate which fields are private, which are required and which are optional.

3.1. Data fields for the system profile

Data fields are divided into the following three groups:

(1) Naming/identification fields;
(2) Work and education-related fields;
(3) Other miscellaneous fields.

The following three glossaries specify the description, purpose, and rationale for including a particular field. Some discussion about use, verification, or special processing of the field may also be included. Each entry specifies whether the field is required to be entered by the user, whether there can be multiple entries for the particular field, or whether the field is provided by the system. Where a data field requires unusual processing (e.g., the publications field), a description of the type of processing is provided.

Fields such as *unique ID number* are created and used by the system and would not be viewable by system end users. It is assumed that the system and administrators can view any profile fields for the purposes of maintaining the system.

- *Last Name* is a required field of one entry. The user can opt to make this field viewable to public and/or other registered users. The combination of last, first and middle name fields will be known as *Full Name*. The system tests for special characters; apostrophes and periods are allowed. (It may be necessary for an additional field for user to designate full name as private or viewable by public and/or other registered users.)
- *First Name* is a required field of one entry that may be viewable by the public. For users with identical names, other fields such as *Display Name* and *Names Published Under* may provide additional identifiers.
- *Middle Name* is a required field of one entry that may be viewable by the public. A standard among systems is to use the middle initial; however, since *full name* is a key, the more explicit the name, the more likely it will be unique, so it is important to encourage users to fill in the full middle name rather than an initial.
- *Personal Title* is an optional field which may include multiple entries and will be viewable by the public. This is also known as *honorific*. Seeing persons' titles may help others address them in communications. For example, *Mr.*, *Mrs.*, *Ms.*, *Dr.* and *other*, with a text box option to fill in another choice, may be presented in a drop-down list.
- *Display Name* is an optional field of one entry which will be viewable by the public. Some users may want to be referred to by something other than their first, middle or last names. The profile would display this version instead of first, middle and last; full name would then appear in *names published under*.
- *Names Published Under* is an optional field of one or more entries which would be viewable by the public. This would allow for inclusion of other names under which an author has published (e.g., maiden name or Americanized names foreign publishers may use). It would help others and the system to identify all publications by that author, and it may help users confirm whether a person authored a particular article.
- *Type Other Name* is an optional field of one or more entries that would be viewable by the public. Note that, in *names published under*, one field each will identify names such as *maiden name*, *Americanized name*, *nicknames*, *pseudonyms*, *anonymous*, *initials used* and *other*. A drop-down list could show these options. A separate field for describing *other* may be provided.
- *Email Address* is a required field with a single entry that would be private, although the user may opt to make it viewable to the public and/or other registered users. The email address will be the login ID and key identifier for the profile record. The system should test to determine if "@" is in the address. Upon providing this field and the password during account registration, the user will receive an auto-sent verification email to the email address provided with a link back to the web site to complete registration. (An additional database field may be needed to ask the user if he or she wants the field private or viewable by the public and/or other registered users.)

- *Password* is a required field with a single entry that would be private. A password is created by the profile owner for login and to protect his or her profile information.
- *Alternate Email Address* is an optional field that could include one or more private entries. Users with multiple email addresses may wish to provide an alternate email. If an original email address no longer works, an alternate address provides another way to contact the user.
- *Unique Identification Number* is a field that is assigned by the system. The system will assign one unique identification number per profile, especially for processing users with identical names.

3.2. Profile naming/identification fields

The *email address* field was selected to be the login identification (ID) because it is a unique identifier and is used by many web sites for account registration. Use of email addresses prevents users from having to create or remember a unique login ID. However, using the email address as the login ID makes the email address part of the key for obtaining access to a profile. Since some users do not want their email addresses made public for various reasons, the email address will not be published or viewable in the profile unless the user expressly states that it can be made public. Because a user's email address may change when changing jobs, giving users a means to update their profiles (and login ID/email address) will be taken into consideration.

An important presentation and design consideration for implementing the use of profiles takes into account that several naming fields are used for identification, though for different purposes. For example, *Display Name* is provided for users who wish to be referred to in communications by something other than a combination of their first, middle and last names.

The three names together represent the *full name*. This field will be useful for automated programs designed to verify an author and/or match a name with other related author databases for possible verification purposes. However, each of the three name fields will be separated in the database schema since trials with other applications have helped to determine that combining those names within one field has been problematic and ineffective.

An author may be referred to in several ways throughout his or her publishing career: a full spelling of the complete name, the last name with only a first initial, or the last name with use of various initials. This can result in one author being accused with another who has a similar name. Unless all the various versions of an author's name are associated, there can be problems for searchers trying to identify all documents for a particular author. One approach for identifying an author and all of his or her publications is to provide fields for authors to include all of the names under which they have published. Two fields address this issue: *Names Published Under*, and a second field that describes the *Type of Name*. The latter can be a drop-down list enabling users to easily select the type of name desired.

The following section describes how profile owners can identify and link their publications and profiles, including publications that use variations of their names. Except for dates and numeric fields, most of the fields listed below are variable length character data fields displayed to the user in the form of a blank text box to be filled in.

3.3. Work and education fields for the profile

The following list shows fields associated with work, education and publications. Note that both the *organization* and *educational institution* as parent fields have respective child fields. For example each organization may have associated fields for *job title*, *job description*, *department* and *from/to dates*. This

provides users with the option to enter a work history and to show multiple institutions or organizations for which they have worked. Users should be able to modify and change the order of organizations by assigning a number to each one. This will allow users to designate their primary/current organizations as opposed to secondary/historical organizations. Note that LinkedIn uses the term *present* in the *To Date* field to represent organizations with which a person is currently affiliated. The *experience* field can include all historical organizations supported.

The *publications* field requires special processing. Because many people have the same last name, and sometimes the same full name, the system cannot accurately identify all correct publications for a particular author. Additionally, while the system can list all publications by authors who share the same last name, as well as those with same last name and initials, the list could be very long. Furthermore, it might not return all of the author's publications under variant names. Therefore, during profile creation/modification, authors can use a search tool to narrow to a list of selectable publications. By changing the search criteria, authors can also include publications under their other names. Once all publications are selected, the system can provide a link between the profile and the publications in order to display them in the viewable version of the profile.

- *Organization* is an optional field of one or more entries. Other registered users can view this field (the public can view the filed if the user selects *public*). This field, along with *job title*, *description*, *department* and *dates from/to* can be entered together for each organization entry, thus providing a work history. This information may also be used by end users when a search by name returns several similar entries.
- *Organization Number* is an optional field consisting of one entry per organization. It is viewable by the profile owner under *Profile Creation*. The profile number is used to order/rank the organizations within the display in the order of importance (or by timeline) and to keep a primary organization listed first.
- *Job Title* is an optional field of one or more entries that is viewable by other registered users. This field can be useful for people seeking a connection with a person with a certain type of specialty or skill, such as a scientist or engineer.
- *Job Description* is an optional field of one or more entries that is viewable by other registered users. Users with multiple roles within an organization can include multiple entries within each organization.
- *Job Role* is an optional field of one or more entries that is viewable by other registered users. Similar to 2collab, the user can select multiples from a drop-down list offering the choices of faculty, librarian, researcher, scientist, student, teacher, or other. A separate field for describing "other" may be provided.
- *Department* is an optional field of one or more entries that is viewable by other registered users. This field is also helpful for resolving searches in large organizations, such as educational institutions.
- *Work Date From* is an optional field consisting of one entry per organization. This field is viewable by other registered users. The *From*/*To Date* fields can provide a timeline for multiple organization entries. The format for dates will be *Year Month Day*; all are optional. If only the day and/or the month are provided, the user should receive an error message. The minimum entry is nothing or year only. Drop-down lists are recommended for *Year Month Day* to reduce potential errors. Displaying dates in order of *Year Month Day* may make it easier for people to omit *Day* and *Month*. Dates will be checked for format and validity.
- *Work Date To* is an optional field consisting of one entry per organization. This entry would be viewable by other registered users. Though both are not required, a *Work Date To* field would be

confusing without an associated *Work Date From* field. The option to pick *Present* will be included in the drop-down lists and displayed as *Present* (following the LinkedIn example). Note that all organizations having *Present* in the *Date To* field would be considered current and could be displayed under a separate subsection for organizations labeled as *current*.

- *Education* is an optional field of one or more entries that is viewable by other registered users. This field – along with *degree acquired*, *dates from/to*, *research area* and *field of study* – would be entered together for each educational institute entry. This field will indicate the name(s) of the institution(s) at which the user studied or worked.
- *Degree Acquired* is an optional field of one or more entries that is viewable by other registered users. This field provides for a list of all types of degrees received.
- *Date From* is an optional field consisting of one entry per education item. It is viewable by other registered users and is used to describe the period during which a user was at a particular institution. The same format for dates applies as described above for *Work Date From*.
- *Date To* is an optional field consisting of one entry per education item. It is viewable by other registered users. See *Work Date To* field above.
- *Research Area* is an optional field of one or more entries that is viewable by other registered users. This field provides for multiple entries for each research area within the educational institution identified.
- *Field of Study* is an optional field of one or more entries that is viewable by other registered users. Users may wish to include fields of study separate or in addition to research areas, and multiple entries could be included for each within the educational institution identified.
- *Publications* is an optional field of one or more entries for which users select from publications displayed by the system. This field is viewable by the public. It identifies all publications by the author as described above and links them to the profile name. This field displays in the viewable version of the profile. Within the editable version of profile, checkboxes will be provided with the list of publications so that users can deselect any publication that was selected previously. A search function will appear at the bottom of the list to allow the user to search for, list and select from additional publications.

3.4. Personal preferences and other profile name fields

The list below includes other fields to be considered for inclusion in the profile, such as contact information and personal preferences.

- *Phone Number* is a required, private, single entry field. This numeric entry is required for verifying profile information by system administrators.
- *Mailing Address* is a required, private, single entry field that is provided as alternate contact information for the phone number. Separate entries for *city*, *state*, *zip code* and *country* will be included according to database conventions.
- *Limit Viewing* is a required, private, single entry field that enables the user to limit viewing of all optional fields (*viewable by other registered users* limits the view to only people who are registered profile users and logged in). This field can be presented to the user using one or two checkmark boxes which are checked to limit viewing by default. For the user's clarity, the two boxes can make it clear whether *limit viewing of optional fields* or *all are available to the public for viewing* is the selected default.

- *Citizenship Country* is a single entry viewable by other registered users. It should be required in systems where the government has stewardship of the information.
- *jpeg Photo* is an optional single entry viewable by other registered users. The user can provide a binary jpeg file; this is intended to be a photo of the user. Since submitted jpeg files could contain sensitive material, the provided file should be reviewed and approved before it is posted in a profile.
- *Interested In* is an optional field of one or more entries that is viewable by other registered users. This field provides a way for users to communicate current fields of interest if they are different than their research areas or if a user chooses not to fill in educational information. This field also provides a free-form text box to express whether a user is seeking or offering other opportunities (e.g., partners for research, collaboration, proposals, cost sharing, fabrication, manufacturing, and/or commercialization on a particular topic). Guidance and suggestions for this field can be provided in help screens to assist users in including useful, relevant information in this field.
- *Interested In Expiration Date* is an optional single entry for each *interested in* field. Other registered users can view this field. This date can be used if a user wishes to have the *interested in* listing automatically removed on a certain date.
- *Home Page URL* is a single optional entry viewable by other registered users. This field would be the URL of the user's home page.

4. Research of barriers to adoption of social networking concepts to scientific collaboration

In addition to understanding collaboration types and profile characteristics, the team also began to identify potential barriers to adoption of social networking concepts.

4.1. User input process – Interviews, polls, etc.

A two-pronged approach, as outlined below, was applied to understand the use of social media in scientific collaboration, as well as perceived barriers to the adoption of social media concepts to research.

(1) The team interviewed individuals in a small, hand-selected focus group in person to define a useful set of collaboration tools. Key points from one of the focus group interviews provide some trending opinions of new social media.

   – A social networking site on narrow topics could be valuable, but it would need to be researcher driven, bottom up.
   – It would be useful to foster more communication from colleagues in specialized areas who only communicate occasionally.
   – There is a goal to avoid overlapping work so that when someone has developed an understanding of a particular system, for example, another researcher does not have to repeat the same effort, but can instead leverage what has already been accomplished.

(2) The team identified a larger group to answer a questionnaire and to provide feedback on a regular basis. One hundred thirty-six (136) among more than 11,000 DOE researchers and authors who expressed interest were selected to participate in providing feedback.

Along with thorough evaluation of comments from the interviews and questionnaires, the team also analyzed studies, literature and online discussions of scientists. Based on comments from several senior researchers, most scientists are only willing to spend time learning new technologies when they can see

a clear and substantial benefit to their research. This observation is consistent with earlier conclusions, and it underlines the importance of creating an intuitive, simple prototype with valuable tools and functionality. It also reinforces the conclusion that the flexibility of today's technology – doing everything for everybody – results in development of complex tools that are difficult for many scientists to use. This exercise generated a list of obstacles that the enhanced prototype would need to overcome to ensure success. This list is presented below.

- *Benefits of social networking are not obvious to researchers: the major barrier to take-up of web 2.0 tools and services is lack of clarity – even among some frequent users – as to what the benefits might be.*
  - The costs of adoption are not always trivial, and unless researchers receive active support and see clear and quick benefits, they tend to keep to the tools and services that they already know and trust. Moreover, the rapid development and proliferation of web 2.0 services is difficult to track or assess for potential benefits [8].
  - Some applications promise a lot of value, yet the users may not see the immediate value [9].
  - Scientists are not really interested in social networking as an end in itself. Rather, they network in order to boost productivity [3].
- *Technologies must be easy to use and take little time/effort to learn.*
  - While technologies used to collect and analyze data often must be cutting edge, collaborative technologies in particular are often best served by technologies that are simple, require very little learning, and are already easily accessible (e.g., wikis and telephones). *Most scientists were reluctant to invest more than a very small amount of time to learn to use new technologies unless the benefits were substantial and related directly to their research* [7].
  - *Widespread adoption of web 2.0 services by researchers depends on their being intuitive, easy to use* and incremental in building on existing practices. Above all, they must offer clear advantages to users, with near zero adoption costs [8].
- *There is a perceived lack of quality and trust without traditional peer review.*
  - A second major set of barriers revolves around perceptions of quality and trust. As producers and consumers of information, *researchers seek assurances of quality, and many of them are discouraged from making use of new forms of scholarly communications because they do not trust what has not been subject to formal peer review.* While a significant minority of researchers believe that peer review in its current forms will become increasingly unsustainable over the next five years, and nearly half (47%) expect that it will be complemented by citation and usage statistics, user ratings and comments, at present, researchers do not see such measures as an adequate substitute for peer review. *Trust is also a concern for researchers who are producing, rather than consuming, information; they are cautious about sharing results and findings in a medium which, as yet, has no standardized way to formally attribute authorship* [8].
  - The major disincentive for many researchers may be lack of trust. Both as creators and consumers of content and services, researchers seek assurances of quality. This study indicates that many researchers are discouraged from using new forms of scholarly communications because they do not trust what has not been subject to formal peer review. *These findings are consistent with other studies, which suggest that researchers seek assurances of quality above all through peer review, and that they do not see citation counts, usage statistics, reader ratings, or other "wisdom of the crowds" tools as providing an adequate substitute* [10].

  - David Resseguie, who wrote "Personal observations at EPSCoR monthly meeting on Exploiting the Use of Social Networking to Facilitate Collaboration in the Scientific Community", stated that some of the barriers to adoption include the lack of reputation information [9], the lack of confidence in individual networks [3], and concerns that personal data might be sold [3].
  - Users may also be suspicious of a site's commercial intentions [3].
  - Data used in networks require provenance and structure, some type of hosting institution or scientific society verifying the credibility of data [3].
  - Sites with no checks on data run the risk of offering less valuable information [3].

- *Sites are perceived as a waste of time*.
  - Some researchers regard blogs, wikis and other such forms of communication as a waste of time, or even dangerous [8].
  - Some non-users go further and believe that these novel forms of scholarly communication bring no benefits. One researcher stated, "I'd rather spend the time thinking about what I'm going to do next rather than spend it telling others what I'm doing... I think it's definitely a younger person's thing" [8].

- *Services need a critical mass of users to be effective*.
  - These obstacles are exacerbated by the fragmentation of the user-base: *few services have yet achieved the critical mass needed to achieve the positive network effects that stimulate pervasive use by particular communities*. Researchers may feel compelled to defer a decision to take up a particular service until they are certain that large numbers of their colleagues have done so [8].
  - There is some debate about whether many of the web 2.0 services for researchers – particularly social network services – provide sufficient added value to stimulate widespread adoption [8].
  - Moreover, the plurality of services results in fragmentation of the potential user base, which is especially problematic when benefits are closely related to the number of users. Because researchers may delay adoption services because large numbers of their colleagues have not done so, the advantages for late movers may outweigh those for early adopters [8].
  - Social networking does not have value if one is simply communicating with oneself [9].
  - No single site provides tools or features valuable enough to lure a majority of busy scientists [3].
  - What can these sites offer that more established sites, such as Facebook, do not [3]?

- *The applications are not integrated*.
  - David Resseguie stated that Yammer has been tried here and a wiki there, but when the applications are not combined into one product, users' attention is divided and usage declines. Some users do not know how to use the applications together [9].

- *Change may conflict with existing practices*.
  - Changes are usually incremental for a number of reasons. *Introducing changes without input from users may conflict with existing practices and be rejected. Moreover, it takes time for new practices to develop around new features, especially if these features radically challenge existing disciplinary patterns of use.* Providers therefore generally seek to align new features with existing services and patterns of usage. Thus, the forums on Nature Networks are very much in the style of conventional bulletin boards, with implicit social rules of behavior and a reasonably active moderator [8].

  - Adoption of web 2.0 tools and services, along with the novel forms of scholarly communication with which these tools are associated, has reached only modest levels up until now. Use is fragmented and uneven, and it tends to support well-established practices [8].

- *Institutional policies can discourage use.*
  - This study provided some evidence that emerging institutional policies may act as a barrier: "In our university, we have a guideline on what may or may not be put onto the blog. I have to agree that something needs to be saved, and I don't want people to say: we just discovered X" [8].

- *Conflict between cooperation and competition can have an impact.*
  - Some scientists may be wary of sharing too much, which likely impedes network adoption. The tension between collaboration and competition is inherent to science [3].

- *The motivation/justification for the research is two-fold.*

This research was motivated by two objectives for application of social media concepts to scientific communication and collaboration, as discussed below.

The first objective was to research and identify web-based tools and other concepts to foster online interaction and collaboration among scientists and researchers with the purpose of facilitating scientific discovery and innovation. This research was funded through an SBIR grant from DOE entitled "Interactive Peer-to-Peer Scientific Communication in the Digital Library Environment".

The second objective was to exploit social networking in order to facilitate scientific collaboration. To this end, efforts were focused on (1) researching and identifying the scientific collaboration styles best served by social networking applications, and (2) modeling the most effective social networking applications to substantiate how social networking can support scientific collaboration. This research was funded by a grant through DOE EPSCoR entitled "Exploiting the Use of Social Networking to Facilitate Collaboration in the Scientific Community". To achieve the second objective, the types of collaborations conducted by scientific researchers were defined through classification, data analysis and identification of unique collaboration requirements. Another aspect of this goal was to understand the current state of technology in collaboration tools.

In support of both objectives, the vast collection of scientific and technical knowledge contained in the DOE digital library collections provided the setting and impetus for this online environment, while the momentum of web 2.0 technologies provided a huge array of technologies and a groundswell of interest from many sectors of the public in online interaction. As a result of researching the characteristics and use of web 2.0 technologies, and by researching interest and use within the traditional community of scientists, tools and approaches were developed and/or identified that would work within the library environment and also attract a wider segment of the scientific community.

With the availability and popularity of many possible web 2.0 social networking applications, it was necessary to research and understand these technologies and to identify which technologies would best serve and attract the scientific community. The popularity and use of applications such as Facebook, LinkedIn and Second Life offer examples of tools to enable and encourage online collaboration. By assembling a focus group of scientists, the team was able to identify the interests and habits of the traditional scientific community and to consider them in the context of social networking applications. The focus group indicated a gap in use of social networking by some members of the scientific community. This provided useful insights about the use and value of various aspects of social networking applications for online communications and interaction.

The research showed that, where there is a specific need, there is a strong interest for participating in online social networking activities such as discussion groups. Research also indicated that, while a scientist may not have joined an existing social networking web site, he or she might have interest in the availability of other scientists' profile information. The research also showed that access to profiles of authors, participants, and others within a network enables communication and interaction.

The research also indicated that there is strong momentum on the web in general, and within the government sector specifically, to enable greater communication, participation, and feedback with the constituencies that the government and websites serve through the use of web 2.0 technologies. Profiles and discussion groups are fundamental applications for enabling this increased dialog.

Through initial feedback, the development of online functions to feature authors, and the planning and design of other functions to provide for interaction, the research team determined that a collection of tools and features would be required to provide an environment rich enough to engage a variety of interests and needs from the community. Through initial feedback and the "architecture of participation" in web 2.0 technologies, the research team immediately recognized the value of engaging the end-users of these tools and functions to participate in their design and testing. This would help optimize the usefulness and adoption of the tools. Initial focus group feedback added significant understanding, allowing the research team to establish several approaches for obtaining additional feedback through email questionnaires of authors from the library collections. Feedback and user interaction were deemed critical to determining the most successful approach and design for development of web 2.0 applications.

4.2. Other benefits are detailed below

Early in the project, it was determined that providing more web-based tools to facilitate more online interaction, communications and collaboration among scientists and researchers would not only facilitate the search, discovery, and communication of scientific and technical knowledge, but it also would provide the mechanisms and the environment to enable dialog, interaction, innovation, and potentially new scientific discovery and knowledge.

By connecting scientists and providing for communities of experts to communicate and interact, the social networking capability of the web can be used to share and create knowledge. This allows the scientist to transcend the office building and local community and to connect to the world of other scientists working on the same problems. While scientists typically work with and know others that work in the same subject area, they may not have immediate access to a global community or have the potential to know of and interact with one another. Web 2.0 social networking tools can connect a scientist with more of the global community and can make all of these resources more accessible.

The new web 2.0 social networking tools make it easier for users to essentially create their own web home pages through profiles. The tools also make it easier for people to find one another, to understand one another's interests, and to contact one another. These tools have the potential to allow people with mutual interests to connect more easily with one another, to create communities of interest, and to broaden their dialog and communication.

5. Summary

During the four years that this research was conducted, a virtual groundswell of interest has developed in the scientific community regarding the use of social media to enhance research experience and to obtain earlier research results amongst peers. In the early part of the research, the only social media tools

available specifically for researchers were a few highly specialized web sites for very small scientific communities. While the funding level of grants for this effort was not sufficient to create, test and deploy a robust set of tools, a beta site was created with a basic set of intuitive tools that were easy to learn. The site was made available for a diverse set of scientists for testing and a good deal of interest in the concept was generated.

However, as time has passed and the marketplace has developed, several commercially viable sites have been developed for the scientific community. With robust funding sources, these will likely survive and prosper.

This research validates the value of these technologies and arms the reader with a vigorous set of features to consider when selecting social media technologies to support scientific research.

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